

What is claimed is:

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1. A metal plating bath comprising an additive consumption inhibiting aldehyde, and a salt of a metal selected from the group consisting of copper, gold, silver, palladium, platinum, cobalt, cadmium, chromium, bismuth, indium, rhodium, ruthenium, and iridium.
2. The metal plating bath of claim 1, wherein the aldehyde comprises an aromatic or non-aromatic aldehyde.
3. The metal plating bath of claim 2, wherein the additive consumption inhibiting aldehyde has a formula as follows:



where R¹ is (C₁-C₂₀) linear, branched or cyclic alkyl; (C₂-C₂₀) linear, branched or cyclic alkenyl; (C₂-C₂₀) linear or branched alkynyl; (C₁-C₂₀) alkyl-O(C₂-C₃O)_xR²; (C₁-C₁₂) alkylphenyl-O(C₂-C₂₀) linear or branched alkynyl; (C₁-C₂₀) alkyl-O(C₂-C₃O)_xR²; or -phenyl-O(C₂-C₃O)_xR²; where x is an integer of from 1-500 and R² is hydrogen, C₃O_xR²; or (C₁-C₄) alkyl or phenyl; the (C₁-C₂₀) alkyl, (C₂-C₂₀) alkenyl, and (C₂-C₂₀) alkynyl may be unsubstituted or substituted.

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4. The metal plating bath of claim 3, wherein the (C_1 - C_{20}) alkyl, (C_2 - C_{20}) alkenyl and the (C_2 - C_{20}) alkynyl are substituted with one or more substituents comprising halogen, aryl, -SH, -CN, -SCN, -C=NS, silyl, silane, -Si(OH)₃, -NO₂, -SO₃M, -PO₃M, -P(R)₂, -OH, -COOH, -CHO, COO(C_1 - C_{12}) alkyl, -CO(C_1 - C_{12}) alkyl, or -NR³R⁴, where R³ and R⁴ are independently hydrogen, aryl, or (C_1 - C_{12}) alkyl; and M is hydrogen, or an alkali metal, and R is hydrogen or a halogen.
5. The metal plating bath of claim 4, wherein the additive consumption inhibiting compound comprises 2,3,4-trihydroxybenzaldehyde, 3-hydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 2,4-dihydroxybenzaldehyde, 4-hydroxy-3-methoxy cinnamaldehyde, 3,4,5-trihydroxybenzaldehyde monohydrate, syringaldehyde, 2,5-dihydroxybenzaldehyde, 2,4,5-trihydroxybenzaldehyde, 3,5-hydroxybenzaldehyde, 3,4-dihydroxybenzaldehyde, 4-hydroxybenzaldehyde, 4-carboxybenzaldehyde, 2-chloro-4-hydroxybenzaldehyde, or benzaldehyde.
6. The metal plating bath of claim 1, wherein the additive consumption inhibiting aldehyde comprises from about 0.001 g/L to about 100 g/L of the bath.

7. The metal plating bath of claim 1, further comprising additives comprising brighteners, levelers, hardeners, wetting agents, malleability modifiers, ductility modifiers, deposition modifiers, or suppressors.
8. The metal plating bath of claim 7, wherein the brighteners comprise compounds having the formulas: $\text{HO}_3\text{S}-\text{R}^{11}-\text{SH}$; $\text{HO}_3\text{S}-\text{R}^{11}-\text{S}-\text{S}-\text{R}^{11}-\text{SO}_3\text{H}$, where R^{11} is $\text{C}_1\text{-C}_6$ alky or an aryl group; or $\text{HO}_3\text{S}-\text{Ar}-\text{S}-\text{S}-\text{Ar}-\text{SO}_3\text{H}$, where Ar is phenyl or naphthyl, the alky and aryl groups may be unsubstituted or substituted with an alkyl group, halo or alkoxy group.
9. The metal plating bath of claim 7, wherein the brighteners comprise 3-mercaptopropylsulfonic acid sodium salt, 2-mercaptop-ethanesulfonic acid sodium salt, bisulfopropyl disulfide, or mixtures thereof.
10. The metal plating bath of claim 7, wherein the levelers comprise alkylated polyalkyleneimines, organo sulfo sulfones, dyes of the phenazine class, phenazine azo dyes, or mixtures thereof.
11. The metal plating bath of claim 7, further comprising the additives 3-(benzthiazoyl-2-thio)-propylsulfonic acid sodium salt, 3-mercaptopropane-1-sulfonic acid sodium salt, bis-ethylenedithiodipropylsulfonic acid sodium salt, bis-(p-sulfophenyl)-disulfide disodium salt, bis-(ω -sulfobutyl)-disulfide disodium salt, bis-(ω -sulfohydroxypropyl)-disulfide disodium salt, bis-(ω -sulfopropyl)-disulfide disodium salt, bis-(ω -sulfopropyl)-sulfide disodium salt, methyl-(ω -sulfopropyl) sodium salt, methyl-(ω -sulfopropyl)-trisulfide disodium salt, O-ethyl-dithiocarbonic acid-S-(ω -sulfopropyl)-ester, potassium salt thioglycolic acid, thiophosphoric acid-O-ethyl-bis-(ω -sulfopropyl)-ester disodium salt, thiophosphoric acid-tri(ω -sulfopropyl)-ester trisodium salt, N,N-dimethyldithiocarbamic acid (3-sulfopropyl) ester sodium salt, (O-ethyldithiocarbonato)-S-(3-sulfopropyl)-ester potassium salt, 3-[(amino-iminomethyl)-thio]-1-propanesulfonic acid, 3-(2-benzthiazoylthio)-1-propanesulfonic acid sodium salt, or mixtures thereof.
12. The metal plating bath of claim 7, further comprising the additives carboxymethylcellulose, nonyphenolpolyglycol ether, octandiolbis-(polyalkylene glycoether), octanolpolyalkylene glycoether, oleic acidpolyglycol ester, polyethylenepropylene glycol, polyethylene glycol, polyethylene glycoldimethylether, polyoxypolypropylene glycol, polypropylene glycol, polyvinylalcohol, stearic acidpolyglycol ester, stearyl alcoholpolyglycol ether, or mixtures thereof.
13. The metal plating bath of claim 14, wherein the bath has a pH of from 0 to about 8.0.

14. A copper metal plating bath comprising an additive consumption inhibiting aldehyde and a copper metal salt.

15. The copper plating bath of claim 14, wherein the additive consumption inhibiting aldehyde comprises an aromatic aldehyde or a non-aromatic aldehyde.

16. The copper metal plating bath of claim 15, wherein the additive consumption inhibiting aldehyde has the formula:



where R^1 is $(C_1\text{-}C_{20})$ linear, branched, or cyclic alkyl; $(C_2\text{-}C_{20})$ linear, branched, or cyclic alkenyl; $(C_2\text{-}C_{20})$ linear or branched alkynyl; $(C_1\text{-}C_{20})$ alkyl- $O(C_2\text{-}C_3O)_xR^2$; $(C_1\text{-}C_{12})$ alkylphenyl- $O(C_2\text{-}C_3O)_xR^2$; or phenyl- $O(C_2\text{-}C_3O)_xR^2$; where x is an integer of from 1-500 and R^2 is hydrogen, $(C_1\text{-}C_4)$ alkyl or phenyl; the $(C_1\text{-}C_{20})$ alkyl, $(C_2\text{-}C_{20})$ alkenyl, and $(C_2\text{-}C_{20})$ alkynyl may be unsubstituted or substituted.

17. The copper metal plating bath of claim 16, wherein the $(C_1\text{-}C_{20})$ alky, $(C_2\text{-}C_{20})$ alkenyl and the $(C_2\text{-}C_{20})$ alkynyl are substituted with one or more substituents comprising halogen, aryl, silyl, silane, -SH, -CN, -SCN, -C=NS, -Si(OH)₃, -NO₂, -SO₃M, -PO₃M, -P(R)₂, -OH, -COOH, -CHO, COO($C_1\text{-}C_{12}$) alkyl, -CO($C_1\text{-}C_{12}$) alkyl or -NR³R⁴, where R³ and R⁴ are independently hydrogen, aryl, or $(C_1\text{-}C_{12})$ alkyl; and M is H, or an alkali metal, and R is hydrogen or a halogen.

18. The copper metal plating bath of claim 17, wherein the additive consumption inhibiting compound comprises 2,3,4-trihydroxybenzaldehyde, 3-hydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 2,4-dihydroxybenzaldehyde, 4-hydroxy-3-methoxy cinnamaldehyde, 3,4,5-trihydroxybenzaldehyde monohydrate, syringaldehyde, 2,5-dihydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 3,5-hydroxybenzaldehyde, 3,4-dihydroxybenzaldehyde, 3,4-dihydroxybenzaldehyde, 4-hydroxybenzaldehyde, 4-carboxybenzaldehyde, 2-chloro-4-hydroxybenzaldehyde, 3-furaldehyde, or benzaldehyde.

19. The copper metal plating bath of claim 14, wherein the additive consumption inhibiting aldehydes comprise from about 0.001 g/L to about 100 g/L of the bath.

20. The copper metal plating bath of claim 14, further comprising additives comprising brighteners, levelers, hardeners, wetting agents, malleability modifiers, ductility modifiers, deposition modifiers, suppressants or mixtures thereof.

21. The copper metal plating bath of claim 20, wherein the brighteners comprise compounds having the structural formula: HO₃S-R¹¹-SH; HO₃S-R¹¹-S-S-R¹¹-SO₃H, where R¹¹ is C₁-C₆

alkyl group or an aryl group; or $\text{HO}_3\text{S}-\text{Ar}-\text{S}-\text{Ar}-\text{SO}_3\text{H}$, where Ar is phenyl or naphthyl; the alkyl and aryl groups may be alkyl groups, halo or alkoxy.

22. The copper metal plating bath of claim 14, wherein the copper salts comprise copper halides, copper sulfate, copper alkane sulfonate, copper alkanol sulfonate, or mixtures thereof.

23. The copper metal plating bath of claim 14, wherein the pH of the electroplating bath is from 0 to about 8.0.

24. A method for plating a metal on a substrate comprising: contacting the substrate with a metal plating bath; and applying sufficient current density to the plating bath to deposit the metal on the substrate; the plating bath comprises a metal salt selected from metals consisting of copper, gold, silver, platinum, palladium, cobalt, cadmium, chromium, bismuth, indium, rhodium, iridium, and ruthenium, and the plating bath comprises an additive consumption inhibiting aldehyde.

25. The method of claim 24, wherein the additive consumption inhibiting aldehyde comprises an aromatic aldehyde or a non-aromatic aldehyde.

26. The method of claim 25, wherein the additive consumption inhibiting compound has the formula:



where R^1 is ($\text{C}_1\text{-C}_{20}$) linear, branched, or cyclic alkyl; ($\text{C}_2\text{-C}_{20}$) linear, branched, or cyclic alkenyl; ($\text{C}_2\text{-C}_{20}$) linear or branched alkynyl; ($\text{C}_1\text{-C}_{20}$) alkyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; ($\text{C}_1\text{-C}_{12}$) alkylphenyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; or phenyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; where x is an integer of from 1-500 and R^2 is hydrogen, ($\text{C}_1\text{-C}_4$)alkyl or phenyl; the ($\text{C}_1\text{-C}_{20}$) alkyl, ($\text{C}_2\text{-C}_{20}$) alkenyl, and ($\text{C}_2\text{-C}_{20}$) alkynyl may be unsubstituted or substituted.

27. The method of claim 26, wherein the ($\text{C}_1\text{-C}_{20}$) alkyl, ($\text{C}_2\text{-C}_{20}$) alkenyl and the ($\text{C}_2\text{-C}_{20}$) alkynyl is substituted with one or more substituents comprising halogen, aryl, -SH, -CN, -SCN, $\text{C}=\text{NS}$, silane, silyl, - $\text{Si}(\text{OH})_3$, - NO_2 , - SO_3M , - PO_3M , - $\text{P}(\text{R})_2$, -OH, -COOH, -CHO, - $\text{COO}(\text{C}_1\text{-C}_{12})$ alkyl, $\text{CO}(\text{C}_1\text{-C}_{12})$ alkyl, or - NR^3R^4 , where R^3 and R^4 are independently hydrogen, aryl, or ($\text{C}_1\text{-C}_{12}$) alkyl; and M is hydrogen, or an alkali metal, and R is hydrogen or a halogen.

28. The method of claim 27, wherein the additive consumption inhibiting compounds comprise 2,'4,'6'-trihydroxyacetphenone monohydrate, 2,3,4-trihydroxybenzaldehyde, 3-hydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 2,4-dihydroxybenzaldehyde, 4-hydroxy-3-methoxy cinnamaldehyde, 3,4,5-trihydroxybenzaldehyde monohydrate, syringaldehyde, 2,5-

dihydroxybenzaldehyde, 2,4,5-trihydroxybenzaldehyde, 3,5-hydroxybenzaldehyde, 3,4-dihydroxybenzaldehyde, 4-hydroxybenzaldehyde, 4-carboxybenzaldehyde, 2-chloro-4-hydroxybenzaldehyde, 3-furaldehyde, or benzaldehyde.

29. The method of claim 24, wherein the additive consumption inhibiting aldehyde comprises from about 0.001g/L to about 100 g/L of the bath.

30. The method of claim 24, further comprising brighteners, levelers, hardeners, wetting agents, malleability modifiers, ductility modifiers, deposition modifiers, suppressors or mixtures thereof.

31. The method of claim 30, wherein the brighteners comprise compounds of the formula:

$\text{HO}_3\text{S}-\text{R}^{11}-\text{SH}$; $\text{HO}_3\text{S}-\text{R}^{11}-\text{S}-\text{S}-\text{R}^{11}-\text{SO}_3\text{H}$, where R^{11} is $\text{C}_1\text{-C}_6$ or an aryl group; and

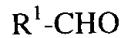
$\text{HO}_3\text{S}-\text{Ar}-\text{S}-\text{S}-\text{Ar}-\text{SO}_3\text{H}$, where Ar is phenyl or naphthyl; and the alkyl and aryl groups may be unsubstituted or substituted with an alkyl group, a halo or an alkoxy.

32. The method of claim 24, wherein the substrate comprises a printed wiring board, an integrated circuit, and electrical contact surface, a connector, an electrolytic foil, a silicon wafer, a semi-conductor, a lead frame, an optoelectronic component, a solder bump, a decorative article, a sanitary appliance and the like.

33. A method for plating copper on a substrate comprising: contacting the substrate with a copper plating bath; and applying sufficient current density to the copper plating bath to deposit the copper on the substrate; the copper plating bath comprises a copper metal salt and an additive consumption inhibiting aldehyde.

34. The method of claim 33, wherein the additive consumption inhibiting aldehyde comprises an aromatic aldehyde or a non-aromatic aldehyde.

35. The method of claim 34, wherein the additive consumption inhibiting compound has the following formula:



where R^1 is $(\text{C}_1\text{-C}_{20})$ linear, branched, or cyclic alkyl; $(\text{C}_2\text{-C}_{20})$ linear, branched, or cyclic alkenyl; $(\text{C}_2\text{-C}_{20})$ linear or branched alkynyl; $(\text{C}_1\text{-C}_{20})$ alkyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; $(\text{C}_1\text{-C}_{12})$ alkylphenyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; or phenyl- $\text{O}(\text{C}_2\text{-C}_3\text{O})_x\text{R}^2$; where x is an integer of from 1-500 and R^2 is hydrogen; $(\text{C}_1\text{-C}_4)$ alkyl or phenyl; the $(\text{C}_1\text{-C}_{20})$ alkyl, $(\text{C}_2\text{-C}_{20})$ alkenyl, and $(\text{C}_2\text{-C}_{20})$ alkynyl may be unsubstituted or substituted.

36. The method of claim 35, wherein the $(\text{C}_1\text{-C}_{20})$ alkyl, $(\text{C}_2\text{-C}_{20})$ alkenyl, and $(\text{C}_2\text{-C}_{20})$ alkynyl are substituted with one or more of halogen, aryl, -SH, -CN, -SCN, -C=NS, silyl, sialne, $\text{Si}(\text{OH})_3$,

NO_2 , SO_3M , $-\text{PO}_3\text{M}$, $-\text{P}(\text{R})_2$, $-\text{OH}$, $-\text{COOH}$, $-\text{CHO}$, $-\text{COO}(\text{C}_1\text{-C}_{12})$ alkyl, $-\text{CO}(\text{C}_1\text{-C}_{12})$ alkyl, or NR^3R^4 , where R^3 and R^4 are independently hydrogen, aryl, or $(\text{C}_2\text{-C}_{12})$ alkyl; and M is hydrogen, or alkali metal, and R is hydrogen or a halogen.

37. The method of claim 36, wherein the additive consumption inhibiting compound comprises 2,3,4-trihydroxybenzaldehyde, 3-hydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 2,4-dihydroxybenzaldehyde, 4-hydroxy-3-methoxy cinnamaldehyde, 3,4,5-trihydroxybenzaldehyde monohydrate, syringaldehyde, 2,5-dihydroxybenzaldehyde, 2,4,5-trihydroxybenzaldehyde, 3,5-hydroxybenzaldehyde, 3,4-dihydroxybenzaldehyde, 4-hydroxybenzaldehyde, 4-carboxybenzaldehyde, 2-chloro-4-hydroxybenzaldehyde, 3-furaldehyde, or benzaldehyde.

38. The method of claim 34, wherein the additive consumption inhibiting aldehyde comprises from about 0.001 g/L to about 100 g/L of the bath.

39. The method of claim 34, further comprising brighteners, levelers, hardeners, wetting agents, malleability modifiers, ductility modifiers, deposition modifiers, suppressors or mixtures thereof.

40. The method of claim 39, wherein the brighteners comprise compounds of the formula:

$\text{HO}_3\text{S}-\text{R}^{11}-\text{SH}$; $\text{HO}_3\text{S}-\text{R}^{11}-\text{S}-\text{S}-\text{R}^{11}$, where R^{11} is $\text{C}_1\text{-C}_6$ alkyl or an aryl group; or $\text{HO}_3\text{S}-\text{Ar}-\text{S}-\text{S}-\text{Ar}-\text{SO}_3\text{H}$, where Ar is phenyl or naphthyl; the $\text{C}_1\text{-C}_6$ alkyl and aryl group may be unsubstituted or substituted with an alkyl group, halo or alkoxy group.

41. The method of claim 34, wherein the copper salts comprise copper halides, copper sulfate, copper alkane sulfonate, copper alkanol sulfonate, or mixtures thereof.

42. The method of claim 34, wherein in the electroplating bath has a pH of from 0 to about 8.0.

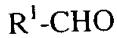
43. The method of claim 34, wherein the substrate comprises a printed wiring board, an

integrated circuit, an electrical contact surface, a connector, an electrolytic foil, a silicon wafer, a semi-conductor, a lead frame, an optoelectronic component, a solder bump, a decorative article, a sanitary appliance and the like.

44. An apparatus for electroplating a substrate comprising an electrical power source electrically connected with an insoluble anode and a cathode such that an electrical current can pass through the insoluble anode and the cathode, the insoluble anode and the cathode are in contact with a metal plating bath comprising an additive consumption inhibiting aldehyde, and a salt of a metal selected from the group consisting of copper, gold, silver, palladium, platinum, cobalt, cadmium, chromium, bismuth, indium, rhodium, iridium, and ruthenium.

45. The apparatus of claim 44, wherein the additive consumption inhibiting aldehyde comprises an aromatic aldehyde or a non-aromatic aldehyde.

46. The apparatus of claim 45, wherein the additive consumption inhibiting aldehyde has a formula as follows:



where R^1 is (C_1 - C_{20}) linear, branched, or cyclic alkyl; (C_2 - C_{20}) linear, branched, or cyclic alkenyl; (C_2 - C_{20}) linear, or branched alkynyl; (C_1 - C_{20}) alkyl- $O(C_2$ - $C_3O)_xR²; (C_1 - C_{12}) alkylphenyl- $O(C_2$ - $C_3O)_xR²; or phenyl- $O(C_2$ - $C_3O)_xR²; where x is an integer of from 1-500 and R² is hydrogen, (C_1 - C_4) alkyl, or phenyl; the (C_1 - C_{20}) alkyl, (C_2 - C_{20}) alkenyl, and (C_2 - C_{20}) alkynyl may be unsubstituted or substituted.$$$

47. The apparatus of claim 46, wherein the (C_1 - C_{20}) alkyl, (C_2 - C_{20}) alkenyl and the (C_2 - C_{20}) alkynyl are substituted with one or more of substituents comprising halogen, aryl, -SH, -CN, silyl, silane, -SCN, -C=NS, -Si(OH)₃, -NO₂, -SO₃M, -PO₃M, -P(R)₂, -OH, -COOH, -CHO, COO(C_1 - C_{12}) alkyl, -CO(C_1 - C_{12}) alkyl, or NR³R⁴, where R³ and R⁴ are independently hydrogen, aryl, or (C_1 - C_{12}) alkyl; and M is hydrogen, or alkali metal, and R is hydrogen or a halogen.

48. The apparatus of claim 47, wherein the additive consumption inhibiting aldehyde comprises 2,3,4-trihydroxybenzaldehyde, 3-hydroxybenzaldehyde, 3,4,5-trihydroxybenzaldehyde, 2,4-dihydroxybenzaldehyde, 4-hydroxy-3-methoxycinnamaldehyde, 3,4,5-trihydroxybenzaldehyde dihydrate, syringaldehyde, 2,5-dihydroxybenzaldehyde, 2,4,5-trihydroxybenzaldehyde, 3,5-monohydrate, 2-chloro-4-hydroxybenzaldehyde, 3-furaldehyde, or benzaldehyde.

49. The apparatus of claim 44, wherein the additive consumption inhibiting aldehyde comprises from about 0.001 g/L to about 100.0 g/L of the bath.

50. The apparatus of claim 44, wherein the metal plating bath further comprises brighteners, leveling agents, wetting agents, malleability modifiers, ductility modifiers, deposition modifiers, or suppressors.

51. The apparatus of claim 44, wherein a pH of the metal plating bath is from 0 to about 8.0.

52. The apparatus of claim 44, wherein the metal salt comprises copper halides, copper sulfate, copper alkane sulfonate, copper alkanol sulfonate, or mixtures thereof.

53. The apparatus of claim 44, wherein the insoluble anode comprises metals of cobalt, nickel, ruthenium, rhodium, palladium, iridium, or platinum.

54. The apparatus of claim 53, wherein the insoluble anode further comprises metals of titanium, zirconium, hafnium, vanadium, niobium, or tantalum.
55. The apparatus of claim 54, wherein the insoluble anode further comprises metals of beryllium, calcium, strontium, barium, scandium, yttrium, lanthanum, or rare earth elements.
56. The apparatus of claim 44, wherein the insoluble anode comprises iridium dioxide.
57. The apparatus of claim 44, wherein the cathode comprises a wiring board, an integrated circuit, an electrical contact surface, a connector, an electrolytic foil, a silicon wafer, a semiconductor, a lead frame, an optoelectronic component, a solder bump, a decorative article, a sanitary appliance and the like.
58. The apparatus of claim 44, wherein the insoluble anode and the cathode have a current density of from about 1 to about 1000 amps/ft².